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PRE-FEASIBILITY DRILLING OF GEOTHERMAL WELL NEAR BOZEMAN HOT SPRINGS TO DETERMINE EXTENT OF GEOTHERMAL RESOURCE

Prepared for

MONTANA DEPARTMENT of NATURAL RESOURCES and CONSERVATION

PRE-FEASIBILITY DRILLING OF GEOTHERMAL WELL NEAR BOZEMAN HOT SPRINGS TO DETERMINE EXTENT OF GEOTHERMAL RESOURCE

Prepared by

Charles Page
Route 4, Box 142
Bozeman, MT 59715

January, 1981

Prepared for

Montana Department of Natural Resources and Conservation
32 South Ewing, Helena, Montana 59620
Renewable Energy and Conservation Program
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OBJECTIVE

The objective of this project was to make a preliminary assessment of the hot water resources at Bozeman Hot Springs by means of drilling into the hot water aquifer or aquifers at the springs site. Flow tests and temperature probe tests have helped determine the quantity and temperature of the water available and will, along with further testing allow evaluation of possible uses.

It was proposed to drill through the clay-silt-sand Gallatin Valley sediment sequence down to Precambrian bedrock in order to test layers of sands for aquifer possibilities. Actual drilling extended a short distance into the bedrock, since the upper, weathered surface of the bedrock contained water-bearing cavities and fractures. The hole was drilled about 75 feet north north-east of the springs near the center of a resistivity low. Previous to drilling this hole, a pre-existing 450 foot deep drillhole, (at the springs site), was deepened to 530 feet. This hole encountered Precambrian bedrock and found hot water at 165 gal. per minute in it. (455-530 ft.)

No funding to design or construct facilities to utilize the waters were requested in this proposal, because it is believed that the nature and extent of the hot water resource must be determined before money is spent on utilization engineering. Potential uses include space heating for homes, apartments, or businesses which may locate in the area; heated warehouses; commercial laundry; warm-water ponds for raising fish; and greenhouses.

SUMMARY OF RESULTS

This drilling project was highly successful. It was anticipated that the project might locate 135-150 gal. of water per minute at a 20 foot head pressure at ground level. Final quanitiy was about 900 gal. per minute with a pressure of 78 foot at ground level!

Water was located in 4 different aquifers. One at 40-55 feet deep in river bottom coarse gravels, producing about 150 gal. per minute and no head pressure. The second was a one foot lens of sand just on top of bedrock 500 feet deep, with 2 gal. per minute at 45 foot head. The third at 530 feet deep had 200 gal. per minute at 78 foot head. The fourth at 545 feet deep encountered an additional 700 gal. per minute at 78 foot head and 129^{o}F. The success of this project is greater than any other recent project in Montana that we know of considering quantity of water, pressure, and temperature. This is very exciting!

PRELIMINARY WORK

Looking back on the project, it could have resulted in a disaster, as we found head pressures that could have resulted in uncontrolled water and could have been extremely expensive to bring under control.

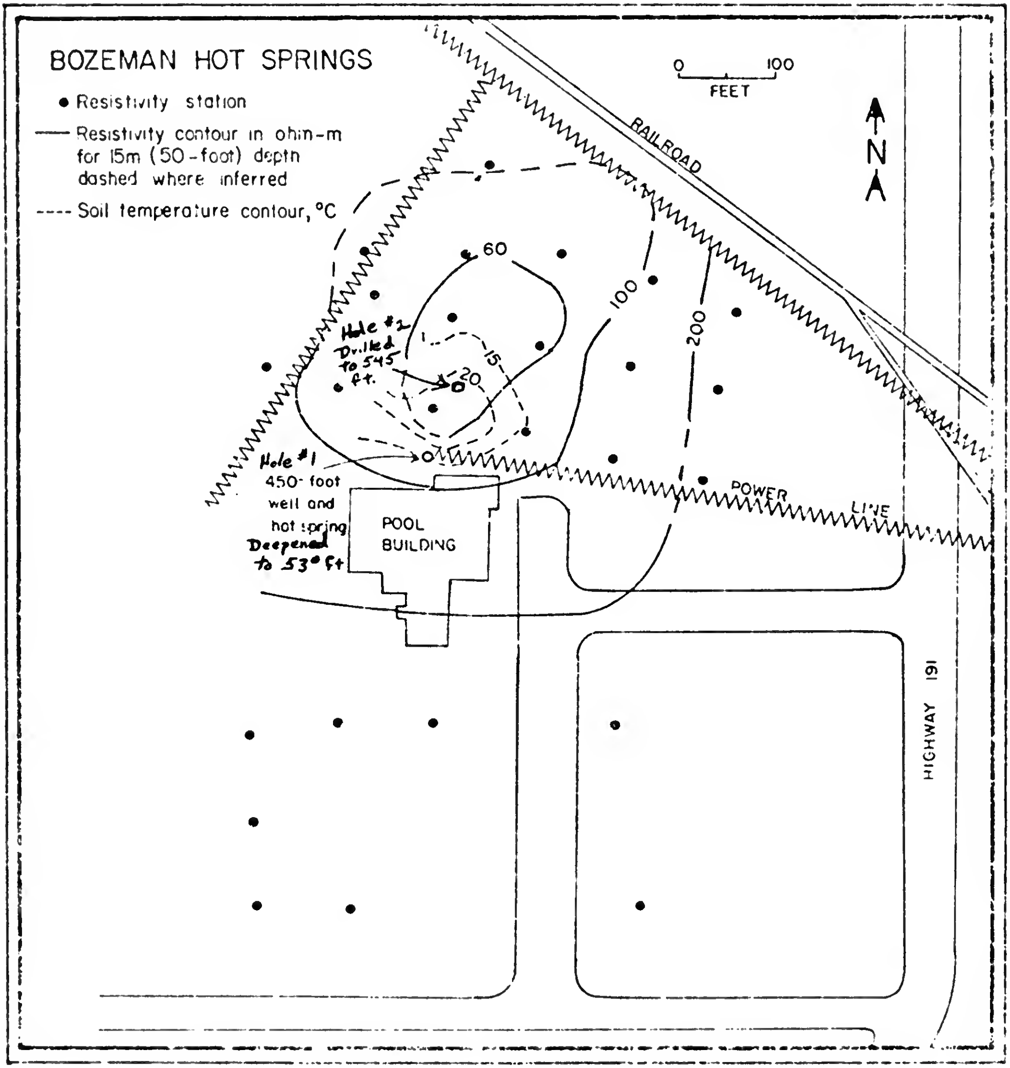
A change had to be made based on findings made after the proposal was written. When this project was proposed, it was felt it was too expensive to run a high speed core test to determine the depth of bedrock. Then it was learned that Boyles Brothers Inc, Drilling would be working in the Ennis area on a Federal Funded Project, and they could move in here without mobilization expenses. They deepened a pre-existing drill hole, (Hole #1), which was located right at the springs site from 455 ft. to 477 ft.. They occomplished this drilling in less than one day at a cost of $2,127.20. From this we learned where bedrock was (at 455 feet), and also the possibilities of a much higher head pressure. From these findings Dr. Robert B. Leonard, Dr. Robert Chadwich and Mr. Darrel Dunn, consulting hydrogeologist, insisted that if we drilled a second hole without definite precautionary measures, a blow out could result, creating a multitude of uncontrolled waters, that may never be able to be brought under control. Or if possible to control, it would be with considerable expense. Although these changes did raise the initial budget somewhat, we now see if their suggestions had not been

followed, we could easily have gotten into major difficulties.

They insisted on:

1. Sealing the casing to prevent a blow-out.
2. Using 8" pipe clear to bedrock. This could be gotten on a rental basis for $825.00. The rental fee could be applied to a purchase price of $3,927.00 if pipe was left in place, or pipe could be pulled for an additional $800.00 if the drilling produced no water or was a failure. They stated that if pipe was not used and a quantity of water was encountered under pressure and allowed to flow to determine quantity and quality for any period of time, it could wash out large cavities due to the fine clays above bedrock.
3. We would have to install an adequate blow-out preventer that could be shut off at all times during drilling.
4. A substructure, or a hill should be built 15' high before drilling into bedrock to install a bypass 10' - 15' below the top of the casing to bleed off water so that if we hit a quantity of water it could be released without going all over men & equipment. And therefore more depth could be drilled before having to call the project to a halt.

Final results showed the wisdom of these above precautions. What a disaster could have resulted without sound judgment!



BOZEMAN HOT SPRINGS
Resistivity station
Resistivity contour in ohm-m for 15m (50-foot) depth dashed where inferred
Soil temperature contour, °C
0 100
FEET
N
RAILROAD
60
100
200
15
20
Hole #2 Drilled to 545 ft.
Hole #1 450-foot well and hot spring Deepened to 53° ft
POOL BUILDING
POWER LINE
HIGHWAY 191

MAJOR DRILLING

I contacted fifteen Well Drilling Contractors. Three were interested and had adequate equipment. These three recommended to try and get a high speed rotary test hole rig, to go down to hard rock with a small test hole. If one of these machines were working in the area, they felt the test hole could be done for $2,000.00 to $3,000.00.

Once the approximate rock depth was known, the driller for the deep well was able to save far more than $3,000.00 by bringing in the right rig and equipment for the job. Our saving was on mobilization and de-mobilization expenses, etc..

We learned on October 1, 1979, that Boyles Bros, from Salt Lake, would have a Chicago Pheumatic RT 1800 test hole rig, (the rig being less than one year old), in the Gallatin area, the last of Oct. or in Nov.. They would run the hole if the site were ready. I decided this was the route to go, even if we had to fund the entire cost of $2,127.00.

The following work was done in preparation for the test hole:

1. We built and installed a blow-out valve assembly with a 4" side valve and injection pipe, so as to pump weighted mud into the hole to stop natural water flow; for use if any excessive pressure was encountered in drilling.

2. We relocated several power and pipe lines close to the drilling site for drilling safety.
3. We prepared a site for a mud pit.
4. We shored up and filled with gravel, an area large enough to support the drilling rig.

On October 18, 1979, we contracted with Boyles Bros., to run the test hole to bedrock in Hole #1, and penetrate rock to the life of the bit. They encountered fractured bedrock at 455 feet. They changed to a short tooth rotary rock bit and drilled to 477 feet, which exausted the life of the bit. Temperature readings were rising at that point.

Darrel E. Dunn, of Earth Science Services, Inc., project hydrogeologist, evaluated this as extremely hard bedrock and together we determined that this contract should end, as we now knew the bedrock or valley floor. Boyles Bros. rig was not set up to effectively drill into bedrock.

We considered Hole #1 highly successful in preparation for drilling the Geothermal Well and Analysis for Hole #2. Costs of this project were rising at a very rapid rate, and it was becoming most difficult to work within our original budget. It was felt that the expenditure of $2,127.20 would be saved by several times, by knowing what we would encounter up to this depth.

It was found that to penetrate this bedrock, we would have to have a high speed down hole hammer rig, from the 460 ft. level. And likely

it would be necessary to install well casing to that point, as the top of the bedrock is badly fractured.

In May 1980, we did further temperature probing in Hole #1 that Boyles Bros. Inc. drilled, and we proceeded to drill on down from 477 ft.. In the 500-530 ft. range we hit 165 gal. per minute of water at 135° to 140° F. in four different levels. Pressure was as high as 70 ft. head. These tests cannot be deemed accurate due to extensive caving, as a result of the pressure forcing debris into the hole. This hole would take further developing or casing, beyond our current budget, to have an accurate test.

We expected to start Hole #2 the following week. But because this was more water at higher pressure than we expected for the completed project, our consultants advised daily monitoring for temperature, pressure and volume, for a few weeks before, during and after high water and mountain snow pack runoff. This monitoring continued another six weeks. Results showed volume and temperature remaining stable.

With this quantity of water, the new hole should be drilled to 8" diameter, it was decided, because we were almost at the capacity of 6" in drilling hardware with this quantity.

Pipe was ordered from Southern Idaho Pipe Corp.. Due to a surplus of extra heavy wall pipe, we were able to secure .322 wall extra heavy for very little over .250 pipe, (which is normally used for well casing). The weight of this pipe would be 30% greater, extending the life of the well by another 20 years. This would be very beneficial if this should

turn out to be a producing well, with no further expense involved.

A cable tool contractor turned out to be far cheaper to drill to bedrock. Into bedrock, a rotary rig would be less expensive. Potts Drilling of Bozeman was the lowest bidder at $50.00 per hour. We contracted with him to set surface casing, and drill to bedrock with a large cable tool rig.

On August 4, 1980, drilling started. September 15, 1980, they completed setting and sealing the casing into 7 feet of bedrock, 500 ft. deep. Total hours were 153½ @ $50 per hour = $7,675.00 ÷ 500 ft. = $15.35 per foot. The normal contracted price per foot on 7" drilling is $20.00 per foot. Our actual cost was under the proposed budget.

For the rotary drilling from 500 feet on down, we found two contractors that were planning to come through the Bozeman area in the Fall of 1980. We contracted with them to stop at Bozeman when they came through. Preston Drilling of Hamilton, MT. was the first one to come. Therefore we cancelled the contract with the other one. This arrangement involved no mobilization & demobilization expense as they were coming through Bozeman anyway.

Preston Drilling had an excellent Chicago Pneumatic CP 650 rotary rig. Drilling began Oct. 27, 1980. Counting setting up and tearing down time, they drilled into bedrock to 545 feet, in 11 hours, (finishing on Oct. 28, 1980). At this depth they were completely drowned out by the volume of water and could go no further.

Geologists and Drillers felt we were at the capacity of the 8" pipe, considering the quantity of air, drilling hardware and debris required in the pipe. Further drilling would require additional amounts of machinery & man power. It was not practical to go any deeper at this time. We had fulfilled the original proposal to drill into the upper fractured layers of bedrock. This amount, temperature & pressure of water would support a sizable development for Geothermal use.

Of the three drilling crews that were on this job, some men with drilling experience of 20-30 years, and drilling thousands of wells, not a man had experienced a producing well of this size, even with cold water.

TESTING

Initial flow tests were higher for the first 24 hours. From 24 to 80 hours, flows and recovery pressures were stable, indicating prolong usage would be stable. Flows were directly measured with a 30 gal. container. At 8 lbs. head pressure, taking the average of 10 counts, it required 2 seconds to fill the 30 gal. container, equaling 900 gal. per minute. At 20 lbs. head pressure it required 5 seconds to fill the 30 gal. container, equaling 360 gal. per minute. Temperature was 129° F. at the beginning of the 80 hour test. Stabilized temperature at the end of 24 hours was at 126° F. and it remained at 126° F. throughout the rest of the 80 hour test. By increasing the head pressure to a 20 lb. head (360 gal. per min.) the temperature rose slowly back to 129° F.. From the test we learned there is considreable underground circulation. And it is not likely that we hit the main conduit of the hot springs, because the temperature of the water is 7° F. lower than the original hot springs here. This may be the result of underground storage water coming in from various fractures from the perimeter of the main hot springs conduit. Another possibility could be a slight contamination of cold water coming in from the outside of the hot springs cone.

Odor and mineral content are simular to the old existing hot spring and are not objectionable for most development. Clarity of water is excellent.

CONCLUSIONS

This project did not call for completing a producing well, but it is recommended that all pipe and valves be left in place and with this we actually have a producing well which can be immediately utilized. This is much more valuable than the original contract budgeted for, and yet the total cost of the project is about the same.

It would seem feasable that an alternate hot water source could easily be found, likely by drilling another hole within 500 feet of this producing well. This should be pursued possibly even before considerable utilization of the producing well. It is far easier to plan and to utilize to a higher degree the available heat source from two sources of water, thus allowing a person to develop and change the hardware from one to the other without interruption of flow.

It is most encouraging that this well has sufficient pressure for use independent of any electric power or pumping source. Even though the pressure is a little low, it would still maintain minimal temperature well above freezing for heating application without any freeze ups in winter months. Some applications may require a 15-30 lb. pumping pressure increase.

ECONOMIC EVALUATION

If the 900 gal. per minute from this well were heated by oil to the 126° F. from the average ground temperature of 50° F., it would require 3,942,000 gallens of oil per year!

Calculation:

1 gal. H_2O = 8 lbs. X 60 min. X 76° rise (50° F. well water to 126° F.) = 36,480 BTU per hour.

So 1 gal. per minute of our new well water = 36,480 BTU. This requires about 1/2 gal. of oil per hour to heat.

900 gal. per minute X .5 (gal. oil) X 24 hours X 365 days = 3,942,000 gal. of oil per year.

5% use of the total energy from the new well = 197,000 gal. of oil @ 90¢ = $177,390.00 ÷ $22,398.88 (total cost of well) = a recovery of the well cost in less than 2 months.

The cost of installing Geothermal water for heating, laundry, domestic water supply, etc. should be under the cost of conventional heating plant and heat exchangers.

It would seem that a feasibility study to evaluate the many potential uses of the hot water, would come up with far greater than a 5% use of this water.

PUBLIC AVAILABILITY

The results of this drilling project can be seen almost any time by the public. It would be well to receive a phone call or letter giving a time for those wishing to inspect the project.

There have been about 30 people who have visited the project so far. These include Michael Chapman from Helena and several men from Montana Bureau of Mires & Geology from Butte.

TOTAL MONEY SPENT TO December 26, 1980, FOR NEW GEOTHERMAL PROJECT AT BOZEMAN HOT SPRINGS

by Charles Page

A. Contracted Services	Job invoice No.	
1. Boyles Bros. Drilling Co. (high speed rotary drilling to determine depth of bed rock - 455')	1	$2,127.20
2. Potts Drilling 153½ hrs. @ $50.00 per hour (Drill, weld, and set surface casing to 160'. Drill, weld, and set 8" well casing into 10' of bed rock 500' deep.)	2	7,675.00
3. Preston Well Drilling 11 hrs. drilling @ $176.00 per hour (hard rock drilling 500' to 545')	3	1,929.00
4. Earth Science Services, Inc. Hydrologist, 5 hrs. @ $25.00	4	125.00
5. Earth Science Services, Inc., Hydrologist, 5 hrs. @ $25.00	5	125.00
6. Intermountain Irrigation Supply, 25 hrs @ $90.00 per hr. (D 8 Cat. with 3 yd. loader to prepare site, 16'high earth large enough for drilling rig and equipment to be on top.)	6	2,250.00
		$14,231.20

B. Supplies and Materials		
1. 154½' surface casing estra heavy .312 wall prim @ $10.36 (from Southern Idaho Pipe Corporation)	7	$ 1,600.62
2. 550' 8 5/8" X .322 wall extra heavy @ $7.14 per foot (from Southern Idaho Pipe Corporation)	7	3,927.00
3. 1 extra heavy drive rock shoe for surface casing (from Intermountain Irrigation invoice)	6	300.00
4. 1 - 8 5/8" extra heavy rock drive shoe for well casing (from Potts Drilling invoice	2	118.00
5. Machine Shop Milling bit rock bit (from Potts Drilling invoice)	2	24.00
6. Rock bit rental, from Potts Drilling invoice	2	50.00
7. Smith-Blair Coupling from Van Dyken Irrigation	8	75.00
8. 2-8" gate valves and pressure gage well head (from Intermountain Irrigation invoice)	6	302.00
9. 2 Smith-Gruner rotary bits @ $250.00 each	9	500.00
10. 1 Ingersoll Rand Bit(LaVelle Powder Co.)	10	650.00
11. 21.6' Prim Drive casing for end of surface casing	2	429.3[illegible]
12. Glenn H. Fritz Co. Freight and Restocking bits	11	160.3[illegible]
13. Freight, returning to Glenn H. Fritz Co.	12	31.[illegible]
TOTAL COST OF PROJECT		$22,398.8[illegible]

These bills and invoices have all been paid in full by Charles Page by a short term note advance from The First Bank of Bozeman, Montana.

MSU

DEPARTMENT OF EARTH SCIENCES

COLLEGE OF LETTERS & SCIENCE

MONTANA STATE UNIVERSITY, BOZEMAN 59717

Jan. 22, 1981

Mr. Charles Page
Route 4, Box 142
Bozeman, Mont. 59715

Dear Mr. Page:

I would like to comment with regard to your results to date on the geothermal drilling at Bozeman Hot Springs.

You now have two drillholes 75 feet apart drilled into Precambrian bedrock beneath valley sediments. Each hole penetrates about 80 feet of the upper weathered and fractured part of the bedrock (a metamorphic gneiss with some evidence of calcite veining). The first hole (deepened from 450 to 530 feet) struck hot water in the Precambrian at a reported flow of 165 gallons per minute. The second hole, newly drilled under the present research project, encountered hot water at an estimated 900 gpm in the 530 to 545 foot depth range (61 to 76 feet below the top of the bedrock). Water temperatures are in the range of 54-56^{o} C, perhaps up to 60^{o} C in zones within the overlying valley fill sands, clays, and gravels.

These results suggest that a substantial quantity of hot water resides in the upper fractured zone of bedrock, probably circulating through fractures and possibly brought up from greater depth along a major fault conduit system somewhere in the vicinity. The water could acquire its heat by deep circulation along such a conduit system.

Unfortunately, it is difficult to get reliable results from short-term flow tests or pump tests on aquifers consisting of rock which is impermeable except for fractures. You might get a strong flow for a time and then suck the fracture dry. Therefore I would recommend additional drilling and pump testing before conclusions about the long-term reliability of the reservoir can be drawn. Geophysical studies such as seismic, resistivity, and thermal gradient measurements might be appropriate as a first step to try to determine the most likely location of a conduit system. If the main conduit can be drilled into, a greater flow of water at higher temperature might be encountered. Even if a main conduit is not tapped, more drilling would determine the lateral extent of the hot water reservoir.

The project is very encouraging so far, and I would hope that the State will be able to continue supporting it with the idea that it may become a "showcase" for low-temperature geothermal utilization.

TELEPHONE (406) 994 3331

Sincerely,

Robert A. Chadwick

BOZEMAN HOT SPRINGS

THERMAL WATER WELL GEOLOGIC REPORT

TO:

Charles Page
Route 4, Box 142
Bozeman, Montana 59715

FROM:

Earth Science Services, Inc.
1115 North Seventh Avenue
Bozeman, Montana 59715

BY:

Darrel E. Dunn
Geologist-Hydrologist

DATE:

January 21, 1981

BOZEMAN HOT SPRINGS

THERMAL WATER WELL GEOLOGIC REPORT

INTRODUCTION

The purpose of this report is to present and interpret the geologic and hydrologic information obtained by the writer from the thermal water well that was drilled at Bozeman Hot Springs. The well is located in the SW¼ of the NE¼ of the SE¼ of section 14, T2S, R4E, Gallatin County, Montana. It was completed October 28, 1980. This report is based on (1) information obtained from microscopic examination of well cuttings supplied by the owner, Charles Page, and (2) observations made during three visits to the site when the hole was at depths of about 130 feet, 470 feet, and 540 to 545 feet, respectively.

LITHOLOGY

A description of the cutting samples that were supplied to the writer is attached to this report. The well penetrated intermontane valley-fill deposits of the Bozeman Group to a depth of approximately 469 feet. At this depth, sample interpretation indicates that the weathered surface of Precambrian gneiss was encountered. The gneiss was penetrated to a depth of about 545 feet.

The 30 and 45 foot samples appeared to be cuttings of coarse surficial gravel. Some chip surfaces in these two samples were covered by white calcareous powder, and a small amount of iron oxide staining was present, but no other precipitates or unusual alteration products were observed.

Samples from depths between 75 feet and 469 feet contained clay, mudstone, siltstone, sandstone and loose sand. These samples were dominantly clay except those from 89 feet to 133 feet, which were primarily sand and sandstone. Calcite was associated with the sandstone and siltstone; it probably represents fracture-filling. Indeed, one flat siltstone surface was coated with calcite. The sandy samples also contained clear chips that looked like quartz. The clay in the samples from 200 feet to 469 feet was soft and plastic, and it expanded when moistened. Most of the clay samples effervesced in dilute HCl, and some looked ashy.

The Precambrian samples (469 feet to total depth) contained limonite and clay that probably represents alteration of the gneiss by weathering at the ancient land surface before it was covered by the clayey deposits of the Bozeman Group. These samples effervesced, and they contained chips of clear calcite that probably represent fracture filling. One large crystal of clear calcite washed out of the hole when it had been drilled to its total depth of 545 feet. Since the well was flowing about 800 gpm, fractures partially filled with calcite are indicated.

HYDRAULICS

Very little water was reported from the surficial gravels and the Bozeman Group. As the Precambrian was drilled below 469 feet, the natural flow of the well increased from about 1 gpm in the upper 10 feet of Precambrian to about 100 gpm by the time 70 feet had been penetrated. Below this depth, the drilling rod began to jump, suggesting fractures; and the natural flow increased abruptly to an estimated 800 gpm as the total depth of 545 feet was approached. Calculations (based on specific capacity and allowing for 27 feet of head loss in the well) yielded a

transmissivity of about 20,000 gpd/ft for the Precambrian penetrated. (This was a crude calculation, and 20,000 gpd/ft should not be used for long term projection of well yield.) This transmissivity value indicates the relative ability of the material to transmit water to a well. It is fairly low compared to values of about 40,000 gpd/ft and 100,000 gpd/ft estimated by the writer for fractured rocks at Broadwater Hot Springs and White Sulphur Springs, respectively. The temperature of the water from the Precambrian at Bozeaman Hot Springs was about 130^{0} F, measured at the discharge pipe while the well was flowing a few minutes after total depth was reached.

COMMENTS

It is convenient to use the word "conduit" to refer to an irregularly shaped mass of relatively permeable rock that transmits hot water from depth toward the ground surface. The conduit would be expected to grade outward to less permeable rock carrying cooler water, and permeability variation within the conduit might be complex. In other words, where ground water is discharging to the surface by upward movement, it seems that the water should move most rapidly and be hottest where the permeability is greatest. Where the permeability is lower in the outer parts of the conduit, the water should move slower and be cooler. If this conception is applied to the Bozeman Hot Springs, it suggests that the well may not have been drilled in the center of the conduit, because the water was only 130^{0} F compared to reported temperatures as high as 140^{0} F at the spring and in shallow aquifers. An alternate explanation is that the well is close to the center of the conduit, but cooler water is pulled in when the well is allowed to flow. An accurate static bottom hole temperature

would probably indicate which explanation is best. Even if the static bottom hole temperature should prove to be low, the well may not be far from the center of the conduit, because large temperature changes may occur within short distances. For example, a difference of 20^{o} F was reported for wells only 100 feet apart at Broadwater Hot Springs near Helena.

Information obtained from this well indicates that a large amount of energy is available. Additional drilling and testing would be required to provide a better evaluation of the total energy available.

BOZEMAN HOT SPRINGS THERMAL WATER WELL

SAMPLE LOG

The following descriptions are for cutting samples supplied by the well owner, Charles Page, and for samples caught at the site by Darrel Dunn. These samples are from the 8-inch well completed on October 28, 1980. The well was drilled by the cable tool method to a depth of about 480 feet. The air rotary method was used from 480 feet to 545 feet. Descriptions are by Darrel Dunn.

DEPTH (ft)	DESCRIPTION
30	Fragmented gravel. Gneiss fragments 95%; basalt fragments, 5%; amphibolite (?), trace. Small amount of iron oxide staining on a few chips. Weathered and rounded surfaces on some chips. White calcareous powder on chips. No unusual alteration products or precipitates observed.
45	As above. One chip of limestone.
75	Mudstone, gray; clay fraction is plastic and very soft when wet; sand fraction, very fine to granule size, some granules are black. Sample also contains sandstone, gray, very poorly sorted, fine to medium grained, with black grains. Few chips of brown limestone in sample.
80	Clay, gray, plastic, sandy; sand grains, very fine to coarse; some black, green and red grains.
89-98	Sandstone, gray, soft, calcareous, very poorly sorted, silt size to coarse grains, angular, heterogeneous, with some red grains and green grains. Much gray clay mixed with sample. Some large chips of clear, crystalline calcite. Many loose grains of clear quartz, coarse, angular.
120	As above, colors more tan.
130	Sand, dark reddish brown, coarse, very poorly sorted, fine to coarse grained, grains of feldspar, quartz, hornblende (?), garnet (?); sandstone, tan, friable, calcareous clayey, very poorly sorted, very fine to coarse grained, some red and black grains; sandstone, light gray, very fine to fine grained, dense, some black and red grains, clayey; clear calcite grains; clear quartz grains; fragments of basalt pebbles; rounded fragments of red silty clay; trace chert chips.

133	As above. Trace of claystone, tan, non-calcareous, hard. Calcite on side of red siltstone chip looks like fracture filling. Chips of basalt (?), andesite (?), hematite (?), chert.
140	Sand, clayey, very poorly sorted, very fine to granule size, about 60% sand and 40% clay. Granules of red siltstone are in the clayey sand, also a granule of brown dolomite. Very soft when wet.
200	Clay, light tan, calcareous, swells when moistened; sandstone, mottled red-yellow-gray, fine to medium grained, non-calcareous, clay matrix; mudstone, red, soft, non-calcareous, contains clear grains that are brittle and do not effervesce. This sample is mostly light tan clay.
250	Clay, light tan, as above; trace of mudstone, sandstone, and silty clay.
300	Clay, light tan, as above, 50%; sandstone, light gray, silty, clayey, grades to sandy, silty clay, may be altered ash, 50%.
350	Clay, light gray, silty, calcareous, red, green and black specks, looks ashy.
375	Caly, gray, calcareous, expands when wetted, probably bentonite.
400	Clay, gray as above; clay, brownish red, trace; black spheres with metallic luster, medium grain size, trace.
425	Clay, gray, as above; clay, gray, with black, green, and red specks, calcareous, expands when wetted.
460	Clay, salmon colored with black mottling, non-calcareous, expands when wetted.
469	Clay, salmon as above; clay, rust colored, trace; numerous angular fragments of clear quartz; small fragments of quartz and mafic minerals. (Probably some Precambrian in this sample.)
475	One large fragment of crystalline rock with quartz, feldspar and mafic (5%) minerals. Considerable iron oxide staining around mafic grains, some weathered feldspar. Sample effervesces and contains small chips of clear calcite. The large fragment does not effervesce.
480	Finely ground quartz, feldspar, and mafic minerals, numerous biotite grains. Effervesces with HCl. Very slow drilling with cable tool.

540 Crystalline rock composed of quartz, feldspar and black mineral(s). Sample effervesces and contains small chips of clear calcite. Some reddish brown staining disseminated through chips of crystalline rock. Spots of red staining on large tabular chips. Numerous black biotite flakes. Trace white, soft material, possibly altered feldspar.

545 As above, some flexible red flakes may be highly weathered biotite. One large chip clear calcite. Some small chips of light green translucent material (epidote ?).

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